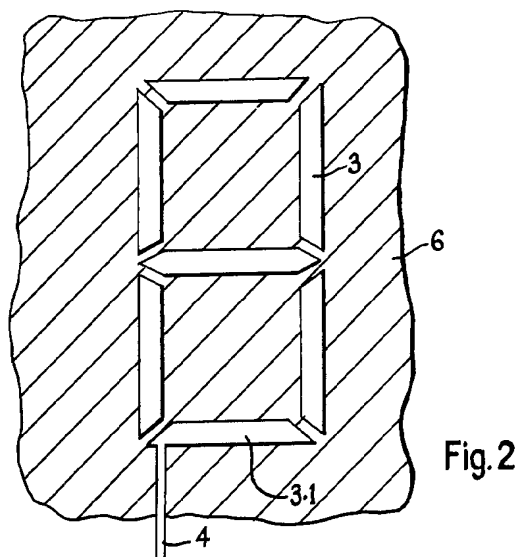
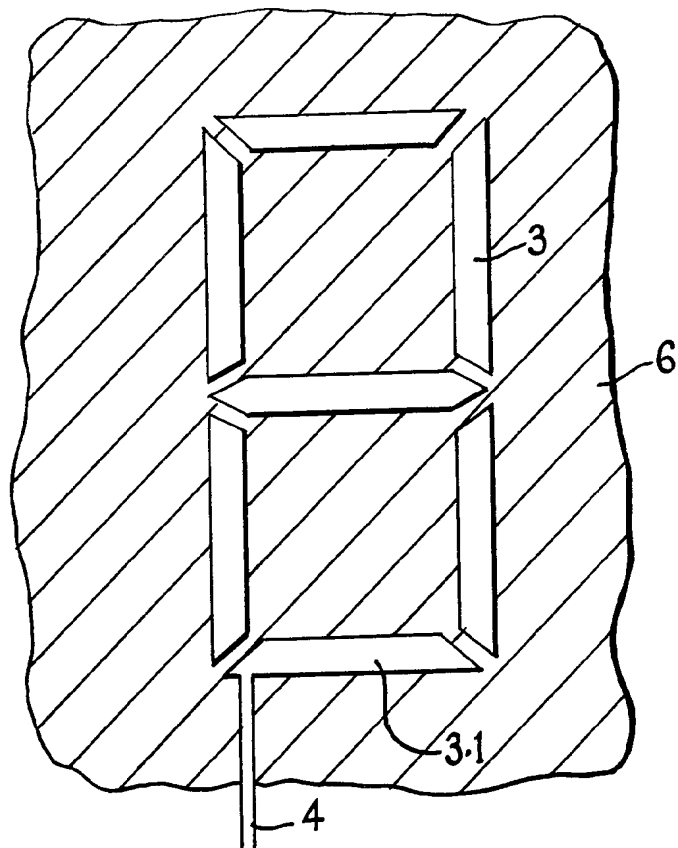
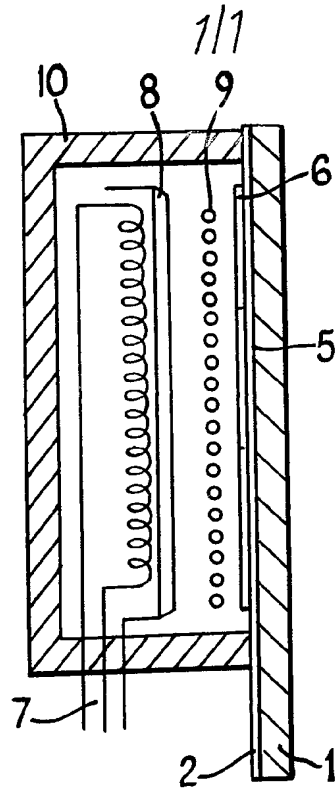


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(54) Vacuum-fluorescent display unit

(57) In a vacuum fluorescent display unit the phosphor coated segments (3) and their light-absorbing surrounds (6) are pigmented so that the colour of the unexcited phosphor matches that of its surround. Preferably this colour is one that contrasts with the fluorescence colour of the phosphor. The phosphor may be zinc oxide which is normally white but fluoresces in red, and cobalt aluminate pigment may be added to it to give it a blue colour in its unexcited state. Preferably the light-absorbing aluminium oxide coating 6 contains the same pigment. If a green colour is desired the pigment may be  $\text{Cr}_2\text{O}_3$  or if a red colour is wanted then  $\text{Fe}_2\text{O}_3$  may be used.





## SPECIFICATION

**Vacuum-fluorescent display unit**

5 The present invention relates to vacuum-fluorescent display units for presenting alphanumeric characters with anodes controllable segment by segment.

Such display units are known in various designs.

10 In vacuum-fluorescent display units of some manufacturers, the phosphor lies behind a control grid which in turn lies behind a cathode filament. In other display units the order of phosphor control grid and cathode is reversed, and the phosphor is located on the rear face of the front substrate which conceals from view the control grid and the cathode which in this case is generally an indirectly heated oxide cathode.

15 In all types of display units, not only in vacuum-fluorescent display, it is customary to take various steps to improve the contrast ratio of the display. These include dyeing the glass substrate or covering the undyed substrate with a light-absorbing coating except in those areas where the image appears. Let the contrast K be defined as follows:

$$25 \quad K = (H1 - H2) / H2 = H1/H2 - 1,$$

where

30  $H1$  = brightness of the bright areas  
 $H2$  = brightness of the dark areas.

From this equation it is readily apparent that, if the signal brightness  $H1$  remains constant, contrast improves as the brightness  $H2$  of the dark areas decreases. The darkening of the nonluminous areas with a light-absorbing coating reduces the brightness  $H2$ , which is due to reflection, and thus improves the contrast K.

40 A disadvantage of this measure is, however, that the contrast between areas covered with a light-absorbing coating and those not covered with such a coating is also increased under nonenergized conditions. Most phosphors have a very bright, usually even white appearance when unexcited. If, as in vacuum-fluorescent display units, this bright phosphor is deposited in the form of segments representing alphanumeric characters, and if these bright phosphor-coated areas are surrounded by areas covered with an absorbing coating, it is obvious that, 50 particularly in high ambient light levels, the phosphor areas contrast sharply against the background even without the phosphor being excited. In very high ambient light levels, if the phosphor has a white fluorescence colour, it may even be impossible to determine whether the phosphor of a digit is glowing due to electronic excitation or whether the digit is visible merely because the white phosphor is brightly illuminated by ambient lighting.

60 The object of the invention is to provide a vacuum-fluorescent display unit wherein even in high ambient light, virtually no difference can be seen between areas which electronically can be made to glow, but which are not at the time being made to glow in this way, and those areas which 65 always remain dark.

According to the present invention there is provided a vacuum-fluorescent display unit having a plurality of anode segments coated with a phosphor and a light-absorbing coating surrounding the phosphor coating on the segments wherein the phosphor is coloured with a pigment and the light-absorbing coating is also coloured to match its colour with that of the pigmented phosphor in its unexcited state.

70 Instead of a white phosphor, that is to say a phosphor that presents a white appearance in its unexcited state, use is made of a phosphor coloured with pigment. The light-absorbing coating used contains a substance having essentially the same colour as the pigmented phosphor in its unexcited state. It is obvious that this measure makes it 80 substantially impossible to distinguish between areas covered with a light-absorbing coating and unexcited phosphor-coated areas even in very high ambient light levels.

85 The colours of the unexcited phosphor coating and of the light-absorbing coating are matched in a particularly simple manner if the light-absorbing coating contains the pigment with which the phosphor is coloured. Practically identical colours can be produced by adding to the light-absorbing coating a 90 nonluminous, white, pigmented substance whose pigment is the same as that of the pigmented phosphor.

By matching the colour of the light-absorbing coating and the unexcited phosphor coating in the manner described above, the entire display area of the display unit can be made to appear uniform, even in very high ambient light levels. If alphanumeric characters are to be displayed, it is particularly advantageous to choose a pigment whose colour differs from the fluorescence colour of the phosphor. It is possible, for example, to choose a red fluorescing phosphor and a blue pigment. Under non-energized conditions, the entire display area will then appear blue. By contrast, alphanumeric characters to be displayed will appear red on a blue background.

100 In vacuum-fluorescent display units in which filaments and control grid lie in front of the phosphor coating, the segmented phosphor areas are particularly advantageously surrounded directly by the light-absorbing coating. In the other design, where the control grid and cathode lie behind the phosphor, it can be advantageous to deposit the light-absorbing coating on the front face of the substrate carrying the phosphor on its rear, and make the phosphor-coated anode segments wider than the areas not covered by the light-absorbing coating.

105 Embodiments of the invention will now be described in more detail with reference to the accompanying drawing, in which:

*Figure 1* is a schematic sectional view of a vacuum-fluorescent display unit, and

110 *Figure 2* shows phosphor-coated anode segments surrounded by a light-absorbing coating.

125 *Figure 1* shows a schematic section through a vacuum-fluorescent display unit of the type where the control grid, and cathode lie behind the phosphor. Deposited on a front substrate 1 is a transparent conductor 2, which serves as the anode. The 130

geometric shape of this transparent conductor is apparent from Figure 2, which is a front view of a substrate as shown in Figure 1. The conductor is divided into seven segments 3, which are arranged in the usual 7-bar array to permit a simple display of digits. A voltage can be applied to these segments 3 via leads 4. In Figure 2, a lead is shown for only one segment, which is designated 3.1. A vacuum-fluorescent display unit may have any number of such digits composed of segments. In a vacuum-fluorescent display unit, the segments 3 usually serve as the anode. A voltage of about 20 - 60 V, typically 30 V, is applied to them.

These anode segments are covered with a phosphor coating 5. The phosphor coating is surrounded by a light-absorbing coating 6, shown hatched both in Figure 1 and in Figure 2. The phosphor coating is excited by electrons from a cathode 8, which is covered with an oxide coating and heated by an independent heater 7. The electron flow between the cathode 8 and the anode segments 3 is influenced by a control grid 9. The entire structure is closed by a cover 10 placed on the substrate 1. The cathode-to-substrate distance is about 1 - 2 mm.

A phosphor coating 5 surrounded by a light-absorbing coating 6 according to the invention can be produced as follows. A desired pattern of anode segments 3 and lead 4 is deposited by conventional phototechniques on a commercially available glass substrate covered with indium tin oxide or some other transparent conductive coating. A suspension of pigmented phosphor in an aqueous solution of polyvinyl alcohol (PVA) and ammonium dichromate (ADC) is then deposited on that side of the substrate having the segments coated thereon, and is dried. This layer is exposed through a mask in those areas where the anode segments 3 are located. The layer hardens in those areas. In the other areas the layer is selectively removed by washing with water. The water washes away unhardened regions but leaves the hardened regions intact. The substrate is then dried. In the next step, a corresponding suspension is applied which contains a light-absorbing substance instead of the phosphor. This layer is exposed in those areas where no anode segments 3 are located. The unexposed areas of the layer are again washed away with water, and the substrate is dried. In this manner, a substrate 1 has been fabricated which supports phosphor-coated anode segments 3 and a light-absorbing coating 6 surrounding these segments. A suitable phosphor is zinc oxide, which has a white appearance when unexcited and a red fluorescence colour. This phosphor may be pigmented, for example, with cobalt aluminate, which imparts a blue colour to it in its unexcited state. If a green colour is desired, a suitable pigment is  $\text{Cr}_2\text{O}_3$  or the substance obtainable from BASF under the trade name "Kobaltgrün". A suitable red pigment is  $\text{Fe}_2\text{O}_3$ , for example. A suitable light-absorbing substance in the light-absorbing coating 6 is pigmented aluminum oxide. Advantageously, use is made of the same pigment with which the phosphor is pigmented.

If a structure is used in which cathode, control grid, lie in front of the phosphor-coated anode

segments then these segments and their surrounding light-absorbing coating are fabricated as described in the foregoing. The fundamental idea of improving contrast by matching the colours of the phosphor coating and the light-absorbing coating is independent of the overall structure of the vacuum-fluorescent display unit.

In a design of a vacuum-fluorescent display unit as shown in Figure 1, the phosphor coating 5 need not necessarily be directly surrounded by the light-absorbing coating 6; it is alternatively possible to deposit the light-absorbing coating 6 on the front surface of the substrate 1 and to form windows in this coating to register with phosphor-coated anode segments on the rear surface. Advantageously, these segments are made slightly larger than the windows in the light-absorbing coating deposited on the front of the substrate. This compensates for parallax errors and ensures that the glowing segments are always visible over their full width even if the display is viewed at an oblique angle.

#### CLAIMS

1. A vacuum-fluorescent display unit having a plurality of anode segments coated with a phosphor and a light-absorbing coating surrounding the phosphor coating on the segments wherein the phosphor is coloured with a pigment and the light-absorbing coating is also coloured to match its colour with that of the pigmented phosphor in its unexcited state.

2. A vacuum fluorescent display unit as claimed in claim 1 wherein the pigment used to colour the phosphor is also used to colour the light-absorbing coating.

3. A vacuum fluorescent display unit as claimed in claim 2 wherein the light absorbing coating is a white substance coloured with the pigment used to colour the phosphor.

4. A vacuum fluorescent display unit as claimed in any preceding claim wherein the pigment used to colour the phosphor is of a colour contrasting with that of the fluorescence colour of the phosphor.

5. A vacuum fluorescent display unit as claimed in any preceding claim wherein the phosphor is located on one face of a substrate and the unit is designed for viewing the phosphor through one or more control grids and cathodes.

6. A vacuum fluorescent display unit as claimed in any claim or claims 1 to 4 wherein the phosphor is located on one face of a substrate and the unit is designed for viewing the phosphor through the thickness of that substrate.

7. A vacuum fluorescent display unit as claimed in claim 5 or 6 wherein the light-absorbing coating and the phosphor are located on the same face of the substrate.

8. A vacuum fluorescent display unit as claimed in claim 6 wherein the light-absorbing coating and the phosphor are located on opposite sides of the substrate, and the anode segments are larger than the corresponding windows in the light-absorbing coating through which the phosphor is observed and that define the inner bands of the light-absorbing coating surrounding each segment.

9. A vacuum fluorescent display unit substantially as hereinbefore described with reference to the accompanying drawings.

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